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Tree-Section Harvesting Of Northern Hardwood Thinnings

James A. Mattson

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Northern hardwoods, broadly defined, cover as much as 100 million acres in the Eastern United States and Canada (Tubbs 1977). They are an important source of valuable timber, as well as aesthetic, wildlife, and recreational resources for many people living in nearby eastern and midwestern population centers. Recent forest inventories have shown that the hardwood resource base is expanding (Birch and Spencer 1986). Volumes are increasing continuously, but the increases are occurring primarily in the smaller size classes. With a young hardwood forest rapidly expanding, opportunities for forest management abound. Smith and Spencer (1985) estimated that in Michigan, 1.4 million acres in the maple-birch type alone would benefit from thinning. These thinnings could produce removals of 1.1 million cords per year.

Besides producing tremendous quantities of raw material, early and repeated thinnings can greatly accelerate growth of high-quality products in these stands. Modern logging equipment can harvest these thinnings, but thinning operations tend to be costly because of the small size and low value of the trees being removed. Fully mechanized whole-tree harvesting operations have been shown to reduce the costs of thinning in pole-size northern hardwoods (Biltonen *et al.* 1976), but whole-tree harvesting can damage residual trees and the site, unless the utmost care is taken in planning and carrying out the operation. New methods are required to selectively cut stands while minimizing site and stand damage. This paper reports on an initial trial of one possible new method for harvesting pole-size northern hardwoods scheduled for a first thinning.

James A. Mattson is a Research Mechanical Engineer, North Central Forest Experiment Station, Houghton, Michigan.

Beginning in the mid-1970's, this method was gradually introduced into Swedish forestry. This method, commonly referred to in Sweden as tree-section harvesting, is a shortwood version of whole-tree harvesting (Nilsson 1984). The system differs from the established shortwood system in that the trees are not limbed after felling. Instead, they are sawn into sections, which are then extracted from the woods, branches and all. In this context, a tree section is simply a section of a stem complete with branches. A small tree comprising a section in itself is also referred to as a tree-section. This system eliminates the costly delimbing of individual trees, the reduced length of the tree sections reduces the likelihood of damage during the extraction phase of the operation, and the trees are completely used. However, the tree sections are more difficult to handle, and load capacity is reduced during extraction and hauling because the tree sections have lower bulk density than conventional roundwood products do.

The tree-section harvesting method was developed in Sweden to accelerate the level of thinning in Swedish forests (Danielsson 1983). Growth and removals are in close balance there, and a higher level of thinning is needed to maintain growth at maximum levels. The universal problem in thinnings is high cost because of small trees. With labor rates and operating costs increasing more rapidly than wood prices, the profit potential of thinning operations is marginal. Mechanization is one solution for meeting increased costs. In Sweden, mechanized conventional shortwood methods have worked well in final harvests and older thinnings where average tree size exceeds 6 inches d.b.h. (diameter at breast height). However, mechanized systems are even more sensitive to tree size than manual methods, and they only slightly lower harvesting costs in 4- to 6-inch d.b.h. stands.

Because delimbing is the most time consuming element in manual harvesting, it was considered the key to developing more efficient methods. Research on alternatives to manual delimbing found the tree-section harvesting method and processing of the tree sections at a central facility to be the best solution for Swedish conditions.

In Sweden, there are two main systems of tree-section harvesting, one partially mechanized and one fully mechanized (Olsson 1985). In the partially mechanized system, the trees are chain-saw felled using directional felling techniques so that the felled trees can be reached by the crane on the forwarder. Initial bunching is also carried out in conjunction with felling. The chain-saw operator must be proficient in directional felling techniques so that the trees are felled and bunched in a pattern that facilitates subsequent bucking and forwarding, and maximizes the spacing of strip roads in the stand. In the fully mechanized system, the felling and preliminary bunching are done with a feller buncher, sized to the trees being harvested.

In both systems, bucking and extraction are performed by a forwarder equipped with a grapple saw. A grapple saw is a hydraulically operated chain saw built into the grapple of the forwarder and controlled by the forwarder operator. With this device, the operator can buck the felled trees while loading the sections onto the machine for extraction from the stand. Tree sections are generally cut into random lengths up to about 18 feet (5.5 m).

Cost estimates for tree sectioning versus conventional shortwood harvesting in Sweden are illustrated in figure 1 (Danielsson 1983). The estimates are for harvesting similar stands by a tree-section system with bunch-delimbing at the mill versus a conventional shortwood operation using a grapple processor. As might be expected, forwarding and hauling costs are higher for the tree-section system, but are offset by the much lower costs for processing. The higher forwarding costs are due to the additional operation of bucking with the grapple saw, and the decreased load capacity because of the lower bulk density of the material being harvested. The reduced bulk density also increases the hauling cost. Processing costs for the tree-section method are reduced by eliminating delimbing in the stand, and by economies of scale in centralized delimbing at the millsite. The difference in felling cost between the two systems is due to the increased utiliza-

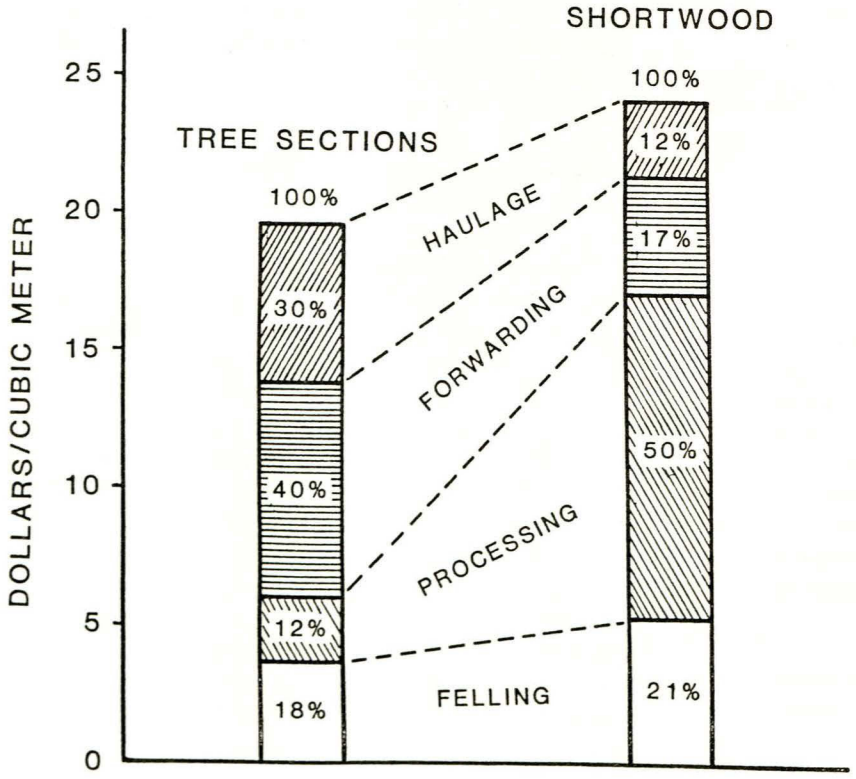

Figure 1.—*Cost estimates for tree-section harvesting versus conventional shortwood harvesting in Sweden (from Danielsson 1983).*

tion with the tree-section harvesting; the felling productivity in trees per hour is the same for both systems.

The main emphasis in the development of tree section harvesting systems has been on thinnings, where the average tree size is in the 4- to 6-inch d.b.h. range and where tree sectioning has been shown to have the largest advantages. Most of the thinning work in Scandinavia is also in conifer stands. Both softwoods and hardwoods are typically removed in these thinnings, so some experience in dealing with hardwoods has been obtained. However, for possible applications to North American conditions, several factors need to be considered. First, the average tree size in thinning operations in North America is generally larger than in Scandinavia. Forest management is not as intensive in North America, and first thinnings are typically scheduled later in the rotation when the trees are larger. For example, an average tree size of 8 inches d.b.h. might be typical in a stand of northern hardwoods being thinned for the first time. Secondly, northern hardwoods of this size generally have larger crowns. Finally, less intensive management results in a wider range of tree sizes.

Some development of tree-section harvesting systems for larger stands is reported in the literature. Nilsson (1984) reports the successful application of tree-section harvesting systems in final fellings where a combination of conventional shortwood harvesting and tree-section harvesting is employed. In these cases, after the trees are felled either manually or mechanically, the larger trees containing saw logs are manually bucked into shortwood for separate forwarding, and the tops of the larger trees and the small trees are harvested as tree sections, using a grapple saw-equipped forwarder. In this way, the highest valued product, the saw logs, are removed conventionally, and the pulpwood and energy wood components are removed as tree sections. A system of tree-section harvesting modeled after this combined approach may be feasible in North America.

STUDY AREA

A stand of typical second-growth, even-age, northern hardwood poletimber was located in Houghton County of the Upper Peninsula of Michigan. The stand, owned by the Elm River Sugar Bush, Inc., is on relatively level terrain well suited to mechanized harvesting. It averaged 279 trees per acre, 5 inches d.b.h. and larger; 128 square feet of basal area per acre; and 8.7 inches d.b.h. The stand was 65 percent sugar maple (*Acer saccharum* Marsh) and 31 percent red maple (*Acer rubrum* L.). The area was divided into three blocks: two treatment blocks (2.4 and 2.6 acres, respectively) and one control block (2.3 acres). Within each of the three blocks, a 1-acre plot was laid out on the ground and detailed measurements were taken on all trees. Subsequent information in this paper is based on data taken from the 1-acre plots.

After initial measurements were made, each block was marked for a selection thinning on a tree-by-tree basis following recommended guidelines (Tubbs 1977). Trees were selected for harvest to release potential crop trees for growth; remove high risk trees, culls, and undesirable species; and thin from below to leave a well-spaced stand of dominant and codominant trees of the desired basal area. Table 1 presents the characteristics of the plots before and after thinning.

Table 1.—*Study plot characteristics before and after thinning*

	Plot 1		Plot 2		Control
	Before thinning	After thinning	Before thinning	After thinning	
Trees/acre	307	148	272	133	256
Basal area (sq ft/acre)	140	81	125	76	119
Average d.b.h. (in.)	8.7	9.8	8.8	10.0	8.7
Crop trees/acre	89	88	73	72	55
Volume/acre (cubic feet)	4,286	2,539	3,851	2,387	3,662
Stand composition					
% Sugar maple	76	60	78	63	84
% Red maple	23	39	20	34	13
% Other	1	1	2	3	3

STUDY DESIGN

We tested a manual intensive method and a semi-mechanized method. A grapple saw-equipped forwarder was not available, so the tree sections were produced with a chain saw in both methods. In the manual method, the trees marked for harvest were felled with a chain saw and were bucked into appropriate length tree sections as they were felled (fig. 2). Any saw logs were bucked into standard lengths, and any material more than about 8 inches in diameter was bucked as standard 100-inch pulpwood. Pulpwood quality material more than 8 inches in diameter would be of higher value than the tree-section material, which would most likely be marketed as energy wood under current market conditions in North America. An alternative would be to handle all the pulpwood quality material as tree sections and process it with a whole-tree chipper. In any case, saw log material would be sorted out because of its higher value.

In the semi-mechanized method, the trees marked for harvest were felled with a Morbark Mark V Feller Buncher with Rapid Bunching Shear[1] (fig. 3). This three-wheeled feller buncher is highly suited to thinning because it is small and highly maneuverable. The severing capacity of this machine is about 14 inches so it cannot handle all the trees typically found in a hardwood thinning. Trees exceeding the capacity of the shear were felled and sectioned by chain saw.

[1]*Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

Figure 2.—*Chain-saw bucking of tree sections.*

Figure 3.—*Morbark Mark V Feller Buncher.*

In both the manual and semi-mechanized methods, tree sections and roundwood were extracted from the stand with a standard Gafner Iron Mule Model 4500 pulpwood forwarder (fig. 4). This standard machine is used for forwarding shortwood in conventional harvesting operations. The only modification we made to the standard machine was to switch the standard grapple on the loader for a "bypass" grapple, which permitted the operator to get a better grip on small bunches of materials. A "bypass" grapple allows the two arms of the grapple to bypass each other and almost completely close the load space between them; on a standard grapple, the ends of the arms come together, leaving a large opening between the arms. Small loads of material were frequently encountered, particularly in the manually felled plot where all the trees were sectioned where they fell. In the machine-felled plot, the operator could build bunches of trees while felling them, thus concentrating the trees and subsequently the tree sections into strategically placed bunches.

All operations involved in both methods were evaluated on the 1-acre plots, using conventional time study techniques to develop productivity information. The material produced was weighed as it was forwarded to the roadside. Tree sections and roundwood were forwarded separately so the quantities of each could be documented and the productivity of forwarding tree sections could be compared to that of forwarding standard roundwood.

RESULTS

The field trial demonstrated that tree-section harvesting can be accomplished in pole-size northern hardwoods. Both the manual technique and the semi-mechanized method worked with a comparable degree of efficiency. A total of 56.8 tons of material were harvested by the semi-mechanized method in block 1, and 51.7 tons of material were harvested by the manual method in block 2 (table 2). The available biomass was almost totally recovered with this harvesting technique. Although we did not sample residual material to determine percent of total recovery, we saw that only a very small amount of material was left in the stand (fig. 5). Where the appearance of the harvesting site is a concern, this near total recovery of the harvested material could be a significant advantage of tree-section harvesting. The lack of logging residue ensures that the site will quickly regain a natural appearance. After one growing season and leaf fall, most of the visual signs of a harvest, such as wheel tracks and displaced litter, will be eliminated.

Figure 4.—*Gafner Iron Mule forwarder extracting tree sections.*

Table 2.—*Time study results for tree-section harvesting*

	Block 1 (Semi-mechanized)			Block 2 (Manual)	
	Chain saw	Feller buncher	Forwarder	Chain saw	Forwarder
Total time(hrs)	12.47	1.72	26.98	24.48	18.90
Productive time	9.45	1.56	20.76	18.17	17.06
Mechanical delay	1.11		3.92	1.35	.91
Non mech. delay	1.91	.16	2.30	4.96	.92
Number of trees	349	286	349	334	334
Number of tons	56.85	39.35	56.85	51.67	51.67
Trees/productive hour	37	183	17	18	20
Tons/productive hour	6.0	25.2	2.7	2.8	3.0

Figure 5.—*Study area after harvesting.*

A total of 349 trees were harvested on block 1 with the semi-mechanized method, and a total of 334 trees were harvested on block 2 with the manual method. It obviously took more time to fell and section the harvested trees with the manual method than with the semi-mechanized method. The Morbark Feller Buncher worked very efficiently in this operation, felling and bunching a total of 286 trees in 1.56 hours of productive time. This equated to 183 trees per productive hour, or 25.2 tons per hour. In this short trial, no mechanical delays were encountered with the Morbark, and only 0.16 hours of non-mechanical delay. The sawyer spent an additional 9.45 productive hours in this plot felling the residual trees that the Morbark could not handle and sectioning all the trees. Average production for the sawyer in this case was 6.0 tons per productive hour. The forwarder spent 20.76 hours of productive time transporting the harvested material to roadside from this plot, an average of 2.7 tons per productive hour. Mechanical delays of 3.92 hours occurred, primarily because of broken hydraulic lines and fittings. The brushy material handled in tree-section harvesting can damage hydraulic lines and fittings. A forwarder used for this type of harvesting should be fitted with additional guarding for vulnerable components to minimize downtime.

The sawyer spent a total of 18.17 productive hours felling and sectioning all the harvested trees on block 2, an average of 2.8 tons per productive hour. This was much less than the 6.0 tons per productive hour achieved on block 1, but not unexpected because the Morbark had already felled and bunched more than 80 percent of the trees on that block. The forwarder spent 17.06 productive hours forwarding the harvested material from block 2 to the roadside, an average of 3.0 tons per hour. Productivity was slightly higher for the forwarder on block 2 than on the block primarily felled with the Morbark. We felt that the more scattered nature of the material on block 2 enabled the forwarder operator to work a little more efficiently. The operator did have to move more in building a load on block 2, but the larger concentrations of tree-sections in block 1 seemed to cause more problems in loading, offsetting the additional moving time.

Post-harvest evaluation of the stand showed much less residual tree damage in block 2, the block that had been manually felled and tree sectioned. Only 1 of 72 potential crop trees in this block was damaged by the harvesting operation, and that one injury was minor. In block 1, the machine-felled block, 28 of 87 potential crop trees were damaged; 7 of them, or 8 percent, had serious wounds. A serious wound was considered to be a wound where more than 50 square inches of bark was removed. This level of damage is similar to that reported by Biltonen *et al.* (1976) for mechanized whole-tree harvesting in a selectively marked thinning operation.

We observed that the higher incidence of residual tree damage in the machine-felled block was caused mainly by the feller buncher. In any thinning operation, the feller buncher has to work in the dense original stand where there is limited room to operate. As the machine works through the stand, the operator can create more working space while removing the trees being harvested, but the operator is likely to bump into residual trees because of the repeated forward and backward movements during felling. We felt this was the cause of many of the tree wounds we observed. In most conventional operations, the skidding or forwarding of the harvested material from the stand is what is felt to cause most of the residual tree damage. The lack of wounds in the manually felled plot in our study illustrates that damage can be minimized by cutting the whole trees down into more manageable lengths for forwarding.

Forwarding the tree-sectioned material from the stand to the roadside was the most difficult part of the operation, as expected. Due to the bulky nature of the tree sections, handling and loading were difficult for the operator, and the loads hauled were smaller than for the roundwood (table 3). While forwarding tree sections, the average load was 3.1 tons, and productivity averaged 2.51 tons per productive hour. While forwarding roundwood, the average load was 4.4 tons, and the productivity averaged 3.83 tons per productive hour, an increase of more than 50 percent in productivity. The forwarder operator in our tests was not a production operator, so his productivity was lower than what would be

Table 3.—*Time study results of forwarding tree sections and roundwood*

	Tree sections	Roundwood
Productive time (hours)	22.34	9.11
Loads	18	8
Tons	56.15	34.87
Tons/load	3.1	4.4
Round trip distance(ft)	1,060	1,361
Loads/productive hour	.81	.87
Tons/productive hour	2.51	3.83

expected of a more experienced operator. However, the ratio of productivity for forwarding tree sections/roundwood would be expected to remain about the same.

It is difficult to compare the two methods of tree sectioning based on productivity alone. The semi-mechanized system used much less time to harvest a comparable amount of material, but of course, the addition of another machine to the system adds considerable cost. Table 4 estimates the cost of the harvesting operation using standard costing procedures (Miyata 1980). The machine rate, or total cost of ownership, operation, and labor per scheduled hour are estimated to be $13.41 for the chain saw, $35.02 for the feller-buncher, and $35.45 for the forwarder (Appendix). On block 1, the Morbark and the chain-saw operator together cut and sectioned the trees, so their combined total cost for the block can be divided by the production for the block to arrive at a per ton cost for wood preparation. The wood preparation cost for block 1 calculated in this manner was $6.06 per ton. On block 2 where the chain-saw operator did all the felling and tree sectioning, the wood preparation cost was $9.43 per ton. Forwarding costs were about the same for both blocks: $19.92 per ton on block 1, and $18.01 on block 2.

Table 4.—*Production cost results for tree-section harvesting*

	Block 1 (Semi-mechanized)			Block 2 (Manual)	
	Chain saw	Feller-buncher	Forwarder	Chain saw	Forwarder
Productive time (hours)	9.45	1.56	20.76	18.17	17.06
Scheduled hours* (SH)	18.90	2.60	31.94	36.34	26.25
Number of tons	56.85	39.35	56.85	51.67	51.67
Tons per SH	3.01	15.13	1.78	1.42	1.97
Machine rate ($/SH)	13.41	35.02	35.45	13.41	35.45
Total cost/acre	253.45	91.05	1,132.27	487.32	930.56
Cost/ton ($)					
wood preparation		6.06		9.43	
forwarding			19.92		18.01
Total cost/ton($)		25.98		27.44	

* Based on standard utilization rates of 50 percent for chain saws, 60 percent for feller-bunchers, and 65 percent for forwarders.

The estimated costs for this trial of tree-section harvesting are quite high compared to costs of conventional operations. Thompson's (1991) cost estimates for producing shortwood with a chain saw and forwarder system in a northern hardwood thinning operation, converted to a per ton basis, were $3.92 per ton for wood preparation and $4.34 per ton for forwarding, for a total roadside cost of $8.26 per ton. However, this study was an initial trial of a new method and the crew were not experienced production operators, so the higher costs are not surprising.

We felt that the skill level and experience of the crew were the major determinant of the high costs in this trial. The data reported by Thompson for an experienced crew doing fairly similar work can be used to estimate the productivity and cost of a tree-sectioning operation carried out by an experienced crew. We can assume that an experienced chain-saw operator could produce tree sections at least as efficiently as shortwood because of the elimination of most of the delimbing required in producing shortwood. Taking Thompson's reported chain-saw production rate of 1.5 cords per scheduled hour and converting to tons per hour gives an estimate of 3.4 tons per hour of tree sections and a cost of $3.96 per ton for wood preparation. In this study, the productivity of forwarding only roundwood was measured to be 2.5 tons per scheduled hour. Thompson reported the productivity of forwarding shortwood at 3.6 cords per scheduled hour, or 8.1 tons per scheduled hour; thus, an experienced operator was forwarding 3.24 times as much wood per scheduled hour as in our study. Applying this ratio to the results we observed gives an overall estimate of forwarding productivity of 6.4 tons per scheduled hour and a cost of $5.58 per ton. These estimates of potential costs would then be a total of $9.54 per ton for tree sections and roundwood at the roadside—15 percent higher than the results reported for a conventional shortwood operation.

DISCUSSION

This evaluation showed that tree-section harvesting is technically feasible in pole-size stands of northern hardwoods. Both the manual and semi-mechanized methods were shown to work in a typical stand with a comparable degree of efficiency. The primary advantages of this technique—almost total recovery of the harvested trees and minimal damage to the residual stand—were demonstrated to be true under the harvesting conditions studied. Residual tree damage was minor particularly with the manual technique.

The costs of the operation evaluated in this study were found to be very high. Estimates of the results that may be expected with an experienced crew were within 15 percent of the costs of conventional shortwood harvesting in northern hardwood thinning operations. Further refinement of the method could result in costs at least equivalent to those for conventional shortwood operations, which would be in line with the results obtained in Sweden. The tree-sectioning technique was developed in Scandinavia where the definition of small trees is much different than in North America. The Swedish results showed that this technique has a definite advantage over conventional roundwood harvesting when the average size of the harvested trees is 11 cm d.b.h. and less. Harvesting costs were about the same when the average size of the harvested trees reached the 14 cm d.b.h. level and above. The 14-cm average size is about 5 inches d.b.h., and the average tree size in the stand harvested in this study was 8.7 inches d.b.h. Based on the Swedish results, it is reasonable that a significant advantage would not be found for tree sectioning in harvesting stands of this size. Forest management is currently much more intensive in Scandinavia, and thinnings are made much earlier in a stand's rotation than in North America. If the intensity of management were to increase in North America, and earlier thinnings were to be made, the tree-sectioning technique could be more productive and cheaper than conventional roundwood harvesting.

Even under current conditions, tree-section harvesting should be considered where the appearance of the harvested site is a primary concern. In harvesting areas such as recreation sites, where maintaining a natural appearance is a major management objective, tree-section harvesting allows a quick return to a natural appearance.

Two areas require further development if the tree-sectioning technique is to be considered for North American conditions. Forwarding equipment will have to be refined to make it suitable for handling the brushy material produced in a tree-sectioning operation. The use of a grapple saw on the forwarder should be investigated. Besides facilitating a completely mechanized operation, the forwarder operator would also be able to selectively break down larger tops and limbs to maximize the load and also to eliminate any large limbs that may damage residual trees as the load is hauled to roadside. This type of operation would also have significant safety advantages over the manual method.

The second area that requires further study is the use of the tree-sectioned material. Complete studies need to be conducted of the systems that carry the tree-section harvested material through appropriate processing operations to a form in which it can be marketed. Conversion of the tree-sections to whole-tree chips or some other product such as chunkwood needs to be studied and the costs need to be documented so that the productivity and costs of the entire system can be documented. Several processing options are available, ranging from whole-tree chipping at the roadside to processing in a central wood yard as is done in Scandinavia. These alternatives should be studied under North American conditions to develop the technical and economic data needed to evaluate an operational application of this technology.

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APPENDIX

MACHINE RATE CALCULATIONS

MACHINE RATE CALCULATIONS
(off-road equipment)

month: July
year: 1991

Description

Machine(make,model,type) Morbark Mark V 3-wheel Feller Buncher

Accessories or modifications _____

Engine(Hp,type) 67 Hp diesel

Initial Investment(P) - F.O.B delivered cost = $ 76,000

Economic Life(n) 5 years

Salvage Value(S) 20 % of P = $ 15,200

Scheduled Hours(SH) per Year 2000 hours

Machine Utilization(U) 60 %

Productive Hours(PH) per Year 1200 hours

Average Annual Investment(AAI) = $\frac{(P-S)(n+1)}{2n} + S$ = $ 51,680 /yr

Ownership Costs

Depreciation(D) - straight line method = $\frac{P-S}{n}$ = $ 12,160 /yr

Interest 12 %

Insurance 4 %

Taxes 1 %

Overhead 8 %

Total 25 % x AAI $ 51,680 /yr = $ 12,920 /yr

Total Ownership Cost per Year = $ 25,080 /yr

Total Ownership Cost per Scheduled Hour = $ 12.54 /SH

Operating Costs

Repair & Service (% of D) 90 % x (D)$ 12,160 /yr / 1200 PH/yr = $ 9.12 /PH

Fuel 67 Hp x 0.026 gal/Hp-hr x $ 1.10 /gal = $ 1.92 /PH

Oil & Lubrication 37 % of the fuel cost = $ 0.71 /PH

Tires $\left(\frac{n \times PH/yr}{\text{tire life}} - 1\right)\left(\frac{1.15 \times \#\text{ tires} \times \text{cost/tire}}{n \times PH/yr}\right)$ = $ 0.71 /PH

Total Operating Cost per Productive Hour = $ 12.46 /PH

Labor Costs

Hourly Wage = $ 10.00 /SH

Wage Taxes 25 % of the hourly wage = $ 2.50 /SH

Fringe Benefits 25 % of the hourly wage = $ 2.50 /SH

Total Labor Cost per Scheduled Hour = $ 15.00 /SH

Machine Rate

Total Cost per SH = ownership + operating x U + labor = $ 35.02 /SH

MACHINE RATE CALCULATIONS (off-road equipment)

month: July
year: 1991

Description

Machine(make,model,type) Gafner 4501F Iron Mule Forwarder

Accessories or modifications

Engine(Hp,type) 60 Hp diesel

Initial Investment(P) - F.O.B delivered cost = $ 65,000
Economic Life(n) 4 years
Salvage Value(S) 20 % of P = $ 13,000
Scheduled Hours(SH) per Year 2000 hours
Machine Utilization(U) 65 %
Productive Hours(PH) per Year 1300 hours

Average Annual Investment(AAI) = $\frac{(P-S)(n+1)}{2n} + S$ = $ 45,500 /yr

Ownership Costs

Depreciation(D) - straight line method = $\frac{P-S}{n}$ = $ 13,000 /yr

Interest	12 %			
Insurance	4 %			
Taxes	1 %			
Overhead	8 %			
Total	25 %	x	AAI $ 45,500 /yr	= $ 11,375 /yr

Total Ownership Cost per Year = $ 24,375 /yr

Total Ownership Cost per Scheduled Hour = $ 12.19 /SH

Operating Costs

Repair & Service (% of D) 100 % x (D)$ 13,000 /yr / 1300 PH/yr = $ 10.00 /PH

Fuel 60 Hp x 0.025 gal/Hp-hr x $ 1.10 /gal = $ 1.65 /PH

Oil & Lubrication 37 % of the fuel cost = $ 0.61 /PH

Tires $\left(\frac{n \times PH/yr}{\text{tire life}} - 1\right) \frac{1.15 \times \#\text{ tires} \times \text{cost/tire}}{n \times PH/yr}$ = $ 0.45 /PH

Total Operating Cost per Productive Hour = $ 12.71 /PH

Labor Costs

Hourly Wage = $ 10.00 /SH

Wage Taxes 25 % of the hourly wage = $ 2.50 /SH

Fringe Benefits 25 % of the hourly wage = $ 2.50 /SH

Total Labor Cost per Scheduled Hour = $ 15.00 /SH

Machine Rate

Total Cost per SH = ownership + operating x U + labor = $ 35.45 /SH

MACHINE RATE CALCULATIONS
(off-road equipment)

month: July
year: 1991

Description

Machine(make,model,type) Chainsaw

Accessories or modifications _____

_____ Engine(Hp,type) _____

Initial Investment(P) - F.O.B delivered cost = $ 650

Economic Life(n) 1 years

Salvage Value(S) 20 % of P = $ 130

Scheduled Hours(SH) per Year 2000 hours

Machine Utilization(U) 50 %

Productive Hours(PH) per Year 1000 hours

Average Annual Investment(AAI) = $\frac{(P-S)(n+1)}{2n} + S$ = $ 650 /yr

Ownership Costs

Depreciation(D) - straight line method = $\frac{P-S}{n}$ = $ 520 /yr

Interest	12 %			
Insurance	4 %			
Taxes	1 %			
Overhead	8 %			
Total	25 %	x	AAI $ 650 /yr	= $ 163 /yr

Total Ownership Cost per Year = $ 683 /yr

Total Ownership Cost per Scheduled Hour = $ 0.34 /SH

Operating Costs

Repair & Service (% of D) 700 % x (D)$ 520 /yr / 1000 PH/yr = $ 3.64 /PH

Fuel _____ Hp x _____ gal/Hp-hr x $ _____ /gal = $ -NA- /PH

Oil & Lubrication _____ % of the fuel cost = $ -NA- /PH

Tires $\frac{(n \times PH/yr}{\text{tire life}} - 1) \frac{(1.15 \times \#\text{ tires} \times \text{cost/tire})}{n \times PH/yr}$ = $ -NA- /PH

Total Operating Cost per Productive Hour = $ 3.64 /PH

Labor Costs

Hourly Wage = $ 7.50 /SH

Wage Taxes 25 % of the hourly wage = $ 1.88 /SH

Fringe Benefits 25 % of the hourly wage = $ 1.87 /SH

Total Labor Cost per Scheduled Hour = $ 11.25 /SH

Machine Rate

Total Cost per SH = ownership + operating x U + labor = $ 13.41 /SH

Mattson, James A.
1993. **Tree-section harvesting of northern hardwood thinnings**. Res. Pap. NC-312. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 16 p.

Describes the results of a field trial of tree-section harvesting, a shortwood version of whole-tree harvesting, in a northern hardwood thinning. This technique is technically feasible and especially useful where the appearance of the residual stand is a primary concern.

KEY WORDS: Mechanization, whole-tree harvesting, shortwood, logging damage, energy wood, aesthetics.

Our job at the North Central Forest Experiment Station is discovering and creating new knowledge and technology in the field of natural resources and conveying this information to the people who can use it. As a new generation of forests emerges in our region, managers are confronted with two unique challenges: (1) Dealing with the great diversity in composition, quality, and ownership of the forests, and (2) Reconciling the conflicting demands of the people who use them. Helping the forest manager meet these challenges while protecting the environment is what research at North Central is all about.

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